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Fig. 1.

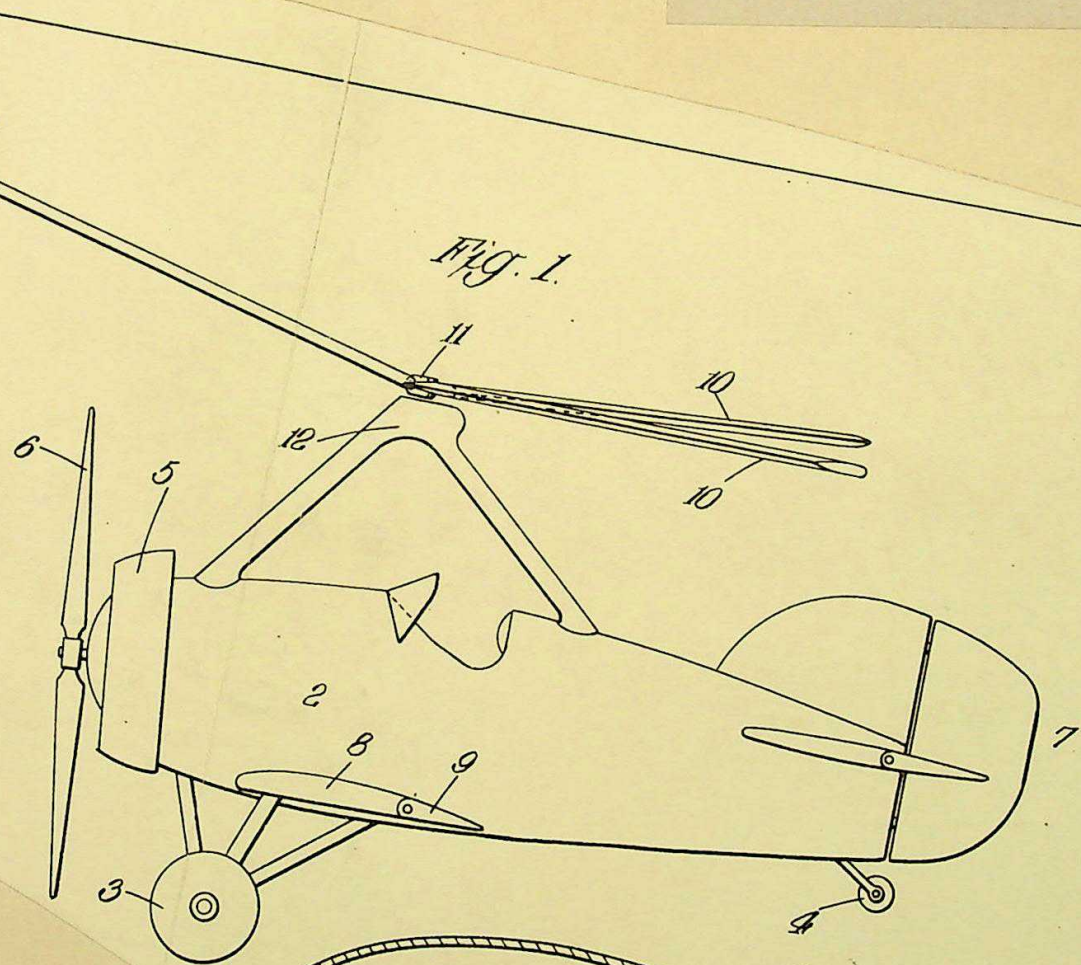
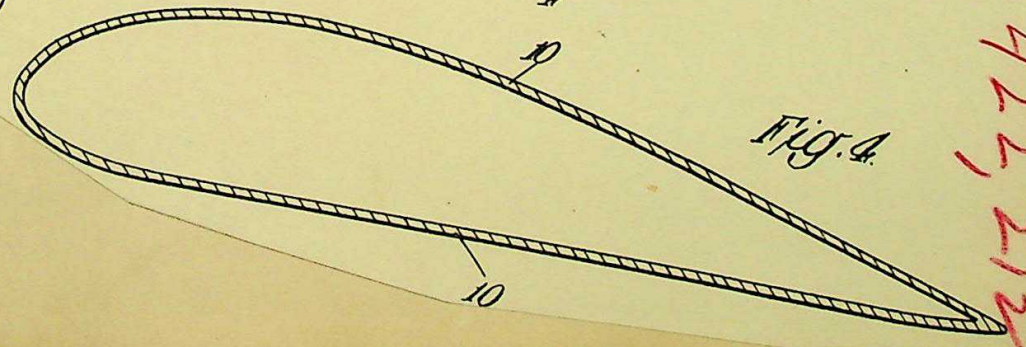


Fig. 4.



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Fig. 2.

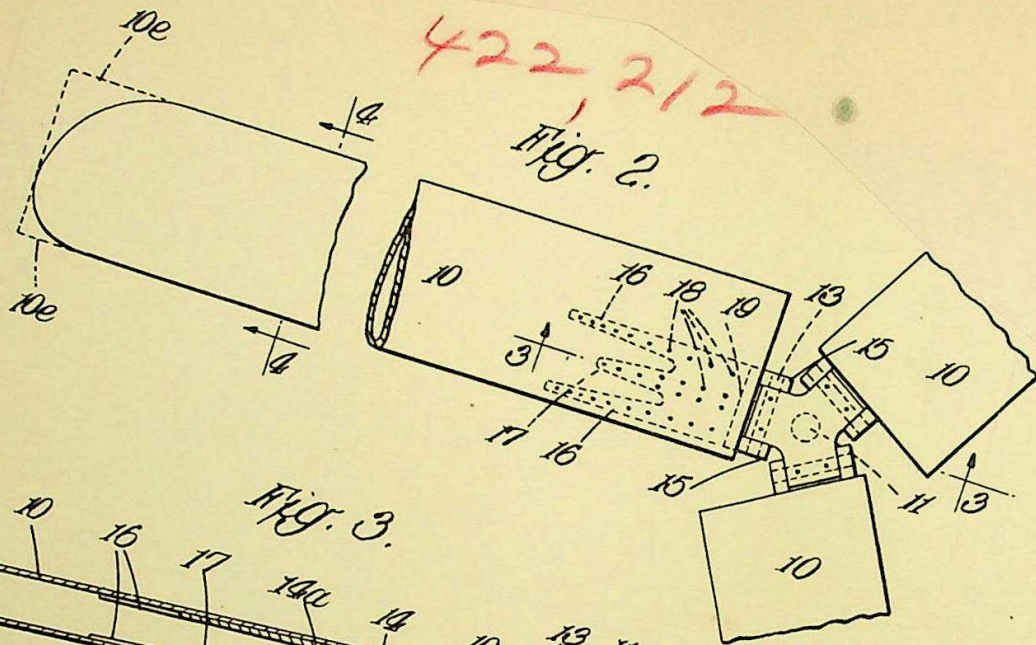


Fig. 3.

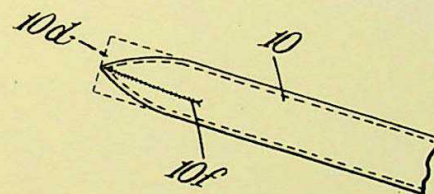
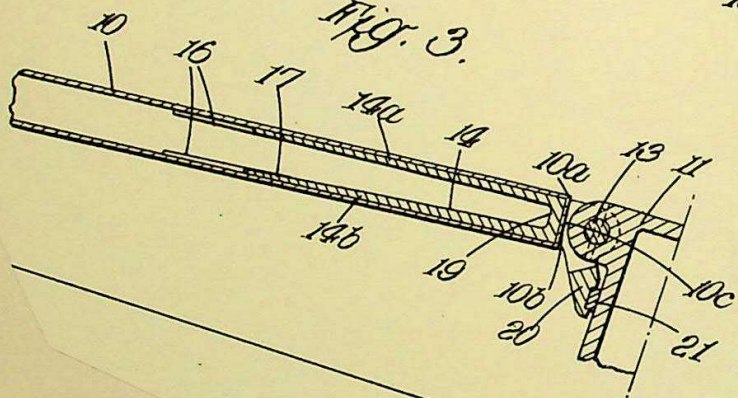
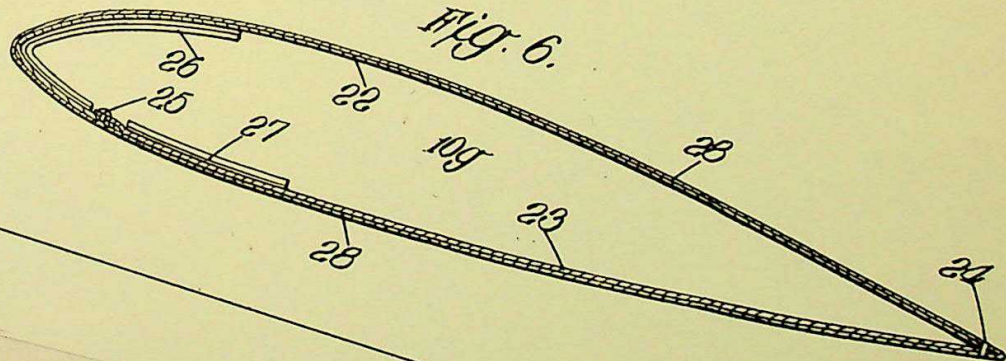


Fig. 5.

Fig. 6.



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EXAMINER'S  
COPY

## PATENT SPECIFICATION

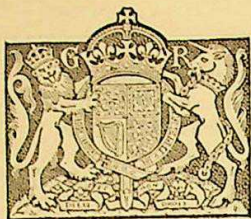
Div. 22

422,212

Convention Date (United States): July 15, 1932.

Application Date (in United Kingdom): July 15, 1933. No. 20103/33.

Complete Specification Accepted: Jan. 8, 1935.



## COMPLETE SPECIFICATION

### Improvements in and relating to Rotor Blades for Aircraft with Auto-rotative Sustaining Rotors

I, JUAN DE LA CIERVA, of Alfonso XII 30, Madrid, Spain, and of Bush House, Aldwych, London, W.C.2, of Spanish Nationality, do hereby declare the nature of this invention and in what manner the same is to be performed, to be particularly described and ascertained in and by the following statement:—

This invention relates to auto-rotative-winged aircraft and more especially to sustaining or air rotors adapted for use in machines of the type in which the wings are rotatively mounted for actuation by the relative air flow produced either by vertical descent or by translational movement of the craft under the influence of its usual propeller and also relates to rotor manufacture.

One of the objects of my invention is to improve the operation of an air rotor, especially of the character just mentioned, both as to its efficiency and as to its smoothness or freedom from vibration.

Another object of the invention is to reduce construction, maintenance and repair costs of, and to simplify, the rotary wing construction.

Still another object of the invention is to utilise the simplified rotary wing structure itself as the primary means for effecting smoother rotor operation. In other words, I have devised a way of simplifying rotor blade construction which at the same time can be used to reduce or prevent resonant or other vibrations in the rotor, which latter are highly detrimental and may even be dangerous.

Further, the present invention contemplates the employment of a simpler rotor blade or wing construction as a means for, or in aid of, simplifying the rotor hub and associated parts.

Broadly, I contemplate the total or substantial elimination of the main longitudinal spar, spars, or other strength members, and at the same time a stiffening of the wing or blade at least in its general plane, and this in such manner that the individual vertically extending pivot pin now normally provided for each blade of the rotor may even be eliminated, especially in machines having small-diameter, high-speed rotors with blades of

very narrow chord. These general objects I preferably obtain by forming the shell or aerodynamic skin of the blade itself as the main (or even the sole) structural blade member, thus reducing to a minimum or even eliminating the ordinary internal longitudinal spar, the internal transverse ribs, and other parts.

In rotor construction such as employed in a pivoted-wing machine in which the wing is pivoted to the hub or axis member by a single articulation located generally transverse the axis of the rotor, stresses have been encountered which in some rotors have produced wear upon the pivot and pivot bearings, and under some circumstances vibration has been quite noticeable. Such stresses and wear have been reduced, relieved or obviated by placing the pivot and the wing spar or wing root in substantially the same plane, that is, by pivoting the wing to its axis by pivot means located at the general plane of the wing and/or by the introduction of flexibility at the root of the wing or the introduction of a vertically extending individual pivot for the blade, so as to relieve the wing, the pivot means, and the mounting of stresses fore and aft in the plane of rotation. However, with certain rotors, there may be vibration and roughness in the rotor during operation, which obviously is unpleasant to the passengers, and ultimately would produce wear of the pivot mounting of the wing and perhaps even in time a weakening of the rotor mounting pylon.

Tests have shown that the major vibrations have arisen from some condition of resonance, due apparently to a synchronism between the rotational period of the rotor and the inherent vibration period of the blade or blades of the rotor or harmonics of the latter. In accordance with the present invention, I take advantage of this fact by stiffening the wing in its general plane of rotation, that is, by increasing its inherent rigidity and thus raising its inherent vibration period; and in conjunction with this I preferably widen the base of support of the single articulation which I provide for the wing. Thus an increase

in the stiffness of the blade, in a direction fore and aft in the plane of rotation, is made; and I preferably make this stiffness of such a degree that the inherent vibration period of the wing or blade is considerably above any rotational speed of which the rotor will be capable in operation, and preferably also above the first or second major harmonics of the rotational speed. Resonant or synchronous vibration is by this procedure so reduced as to make it quite advantageous to utilise but a single articulation for the wing, which articulation is preferably by means of a substantially elongated pivot or bearing, located generally in the plane of the wing or of its root end, and extending preferably substantially transverse the general axis of rotation of the rotor.

In addition to advantages hereinbefore mentioned, the present invention contemplates the elimination of inter-blade cables and cumbersome droop support cables; reduction of the number of parts making up the rotor hub; the simplification of the blade to a form in which it is made up of only one piece, or of a few unified pieces; the production of an all-metal blade and supporting structure, and the improved carrying of the stresses from the blade itself to and through its attachment fitting or fittings. In general, these and other objects are obtained by forming the blade either of a plurality of stamped or rolled sections, suitably interconnected to form a hollow shell, or preferably by making it of one-piece tubular construction; whereby the skin or shell of the blade itself takes all of the major part of the centrifugal, pressure, torsional, vibrational and other stresses encountered in flight. The rotative blade or wing according to this invention, may be formed or drawn either of symmetrical or non-symmetrical camber or profile; and, as shown in the present disclosure, it is preferably of uniform chord and profile, except for the extreme outer tip portion, of uniform wall thickness from end to end, and of the same built-in pitch from end to end.

How the foregoing and other objects and advantages which are incident to the invention and which will occur to those skilled in the art are obtained, will be evident from the following description taken together with the accompanying drawings, in which drawings:—

Fig. 1 is an outline side elevational view of a rotary-winged aircraft embodying the rotor and rotor blades of the present invention, the rotor shown being a three-blade rotor.

Fig. 2 is a fragmentary plan view of the rotor employed on the craft, the Figure being taken on a somewhat larger scale.

Fig. 3 is an enlarged view approximately on the line 3—3 of Fig. 2.

Fig. 4 is a further enlarged view on the line 4—4 of Fig. 2.

Fig. 5 is an elevational view of the leading edge of the outer or tip portion of the left hand wing or blade of Fig. 2; and

Fig. 6 is a sectional view similar to Fig. 4 of a modified form of the invention, embodying a blade of different profile formed of rolled or pressed sections of a different material, and with some internal stiffening.

In Fig. 1, the aircraft 2, having undercarriage 3—4, engine and propeller 5—6, empennage 7 and small fixed wings and ailerons 8—9, is provided with a primary sustaining system of rotative wings 10 flexibly or pivotally secured to a rotative hub 11 mounted on the pylon or supporting structure 12. The type of rotor employed is one in which each wing, as the machine moves translationally, may at least to some extent rise and fall, during its circle of rotation, in order to compensate for differences in flight forces, primarily differential lift forces on the several wings.

In Figs. 2 and 3 it will be observed that the rotary blade or wing 10 is of drawn tubular construction secured to the hub 11 by means of a pivot or bearing member 13, positioned generally in the plane of the root end of the wing and extended generally horizontally or transverse the common rotational axis. Since the wing has no spar, or may itself be considered as being its own spar, it is preferably secured to the hub through the intermediation of a fitting 14.

Externally of the blade itself, the fitting preferably has a pair of widely spaced apart lugs or ears 15, so as to accommodate a wide hub portion and a very long pivot pin 13. Internally of the blade or wing the fitting 14 may be divided into upper and lower portions 14a, 14b, preferably split into tongues or forks 16 and 17, which may be secured as by riveting, or more preferably spot welding (as shown at 18), to the inside of the upper and lower faces of the wing. At the very inner or root end of the blade the fitting 14 has a heavy transverse portion 19, extending across the attaching lugs 15, and over the inner face of which the blade shell may be bent; the upper part of the shell being bent down as indicated at 10a and the lower part being bent up as indicated at 10b, the two parts being preferably welded together along the line 10c, to

assist in securing the blade to the fitting, and to close off the root end of the blade, so as to keep out moisture and the like, the lugs 15 being allowed to project as shown. If preferred, a separate closure member or plate may be employed, instead of bending over the blade surfaces 10a, 10b. The only additional structure necessary besides the hub itself and its internal bearings (not shown), is the transverse member 20, extending across between the attaching lugs 15, and located in a position to support the rotor blade against excessive downward droop when idle, through the intermediation of a small bumper block, preferably of rubber, indicated at 21, which may bear against the periphery of the hub member 11.

The drawn metal wing may be formed of some light metal material, such as any suitable aluminium alloy, and in Fig. 4 it will be seen that such a construction forms a continuous shell, which, in section, may be of non-symmetrical camber, and which is of integral form and preferably of substantially uniform wall thickness, the thickness being made ample to care for all loads and stresses carried by the blade, including the centrifugal force thereon, the lift force and other pressures, and any torsional or twisting force. The structural incidence of the blade may be (when at rest) substantially uniform throughout the major portion of its length.

In forming the blade itself, which may be of a single piece from end to end, the tube may be drawn out, to any desired sectional shape and thickness, and in lengths equal to more than one blade if desired. From the drawn tube, a full-length blade section may be cut straight off as indicated at 10d in Fig. 5. Viewed in plan (Fig. 2), the corner portions 10e may then be cut off on the proper curvatures for a smooth stream-line tip. It should, however, be understood that the full length of the blade shown in Fig. 2 would normally be approximately twice as long as the length there shown, for the chord indicated, or perhaps even a little longer. The upper and lower curved end portions are then brought together, as shown in Fig. 5, and welded along the line 10f. A sealed, hollow tubular blade or wing, which is its own spar, thus results. At the root end of the blade the fitting 14 (which may be a forging) is secured in place, the root end of the tube being bent over and welded along the chord line 10c and preferably also welded to the part 19 of the fitting; and to give an extremely smooth, efficient and neat surface the entire blade may be spray-painted or finished with enamel or some other suitable impervious coating, which will

also protect the blade from the elements.

Referring now to the modification of Fig. 6, it will be seen that I have shown a symmetrically cambered rotative wing 10g, which may be made of thin, stainless, sheet steel, upper and lower plates 22—23 being stamped, rolled, or bent to form, brought together, and joined at intervals longitudinally thereof, as by means of rivets 24 and 25. Adjacent the high-pressure areas of the section, there may be applied to the sheets, before assembling, internal flange-strip stiffeners 26 and 27 at intervals along the length of the wing. A protective and smoothing coating 28, such as above described, is shown as applied to the blade or wing in Fig. 6.

The form of construction of Fig. 6, as well as the form shown in the other Figures, may be secured to the pivot bearing or bearings of the hub by a fitting 14 similar to that heretofore described; it being understood that a sheet-steel blade or wing is preferably welded to the fitting, while one of aluminium alloy or other material is preferably attached by rivets or screws.

The tapering of thickness of the internal plate-like members 14a—14b of the fitting 14, the spreading or divergence of the forked ends 16—17 thereof, and the provision of a plurality of weld points, screws, rivets or the like 18, all cooperate to produce a gradual distribution or transfer of the centrifugal and other thrusts and loads from the tubular wing to the fitting itself and thence to the hub, and also provide a substantially self-supporting wing structure, when the wing is in drooped position, at rest, as in Fig. 3.

The elimination of cables with their whipping and vibration, the provision of a wide base for the elongated wing pivot 13 with resultant simple and rugged hub, and a substantial increase in rigidity of the wing, especially in its plane, with resultant material raising of the inherent vibration period thereof, all cooperate to produce smooth wing and rotor operation, to obviate resonant vibrations even when the vertical pivot for the wing is omitted, and to make the entire rotor aerodynamically cleaner and more efficient.

Having now particularly described and ascertained the nature of my said invention and in what manner the same is to be performed, I declare that what I claim is:—

1. For use in an aircraft having an autorotative sustaining rotor of the kind first referred to, a rotor-constituting wing or blade of aerofoil shape which includes, as a major part of its aerofoil-shape-defining structure, a unified elongated

- metallic tubular shell member, said member constituting the major element for carrying the centrifugal, aerodynamic and other loads imposed on the blade in operation. 5
2. A rotor blade as claimed in Claim 1 whereof the metallic tubular shell member is of substantially uniform cross-sectional contour throughout a large part of its 10 length.
3. A rotor blade as claimed in Claim 1 or Claim 2 whereof the metallic tubular shell member is of substantially uniform wall thickness in all parts of a given cross- 15 section thereof.
4. A rotor blade as claimed in any of the preceding Claims whereof the metallic tubular shell member is of substantially uniform wall thickness along a given line 20 throughout the major portion of its length.
5. A rotor blade as claimed in any of the preceding Claims and of substantially uniform pitch angle throughout a major portion of its length, when unloaded.
- 25 6. A rotor blade as claimed in any of the preceding Claims, whereof the metallic tubular shell member is formed of a plurality of stamped or rolled sections joined together to form a hollow shell.
- 30 7. A rotor blade as claimed in any of the preceding Claims, whereof the metallic tubular shell member is of one-piece drawn tubular construction.
8. A rotor blade as claimed in any of 35 the preceding Claims which includes a root fitting of considerable width in relation to the blade chord attached to a substantial area of the metallic tubular shell member and adapted for pivotal mounting on the rotor hub assembly. 40
9. A rotor blade as claimed in Claim 8, whereof the root fitting is attached to the metallic tubular shell member in a manner ensuring gradual or progressive distribution or transference of the centrifugal 45 loads from said shell member to the pivot portion of said fitting.
10. The method of manufacturing a rotor blade for an aircraft of the kind herein first referred to, which method 50 comprising shaping a metallic material to a tubular form of which the cross-section constitutes the whole or part of an aerofoil profile, closing up an end of the tube and attaching a mounting fitting to an end of 55 the tube.
11. A method as claimed in Claim 10, which includes bending over and sealing both ends of the tube and applying to the tube a smooth substantially impervious 60 coating.
12. A rotor blade for aircraft of the kind herein first referred to constructed substantially as herein described with reference to and as shown in the accompanying 65 drawings.

Dated this 15th day of July, 1933.

TONGUE & BIRKBECK,  
Bank Chambers, 329, High Holborn,  
London, W.C.1.  
Agents for the Applicant.